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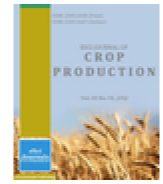

EFFECT OF FERTILITY MANAGEMENT ON PLANT PARASITIC NEMATODES AND MAIZE YIELD UNDER LONG-TERM CONTINUOUS CROPPING IN NORTHERN GUINEA SAVANNA OF NIGERIA

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A B S T R A C T

Continuous intensive cropping has adversely affected soil quality and crop yield thereby threatening the sustainability of intensified maize-based systems in the northern Guinea savanna of Nigeria. A field study was carried out at Zaria under a long-term maize trial established in 1997, to evaluate the effect of soil fertility amendments on plant parasitic nematodes and yield of maize. The experiment was laid out in a randomized complete block design. The treatments were made of urea fertilizer, animal manure, *Centrosema pascuorum, Vigna unguiculata* and applied to make 45 and 90 kg N ha^{-1}.used as either sole or mixed fertilizer treatments. Results obtained showed that incidences of plant parasitic nematode infection were significantly reduced between 3.4- 80% in soil by the mixed application of urea fertilizer and animal manure compared to sole urea application at 90 kg N ha^{-1}. With the application of 45 kg N urea + 45 kg N animal manure (7.5tons ha^{-1} cow dung or 1.5tons ha^{-1} poultry litter), maize yield was not significantly different from yields obtained at 90 kg N sole urea fertilizer application, suggesting that manure improved the soil quality, reduced use of urea fertilizer and attained statistically similar yield level with 90 kg N sole urea fertilizer to be seen as a better soil fertility management strategy. Principal component analysis indicated that plant parasitic nematode genera *Pratylenchus* and *Aphelenchoides* sp. influenced grain yield negatively, but their dominance in the soil was identified as one of the yield-reducing factors. To maximize maize productivity in the northern Guinea savanna of Nigeria, adoption of a "balanced" fertilization that combines urea fertilizer with animal manure to restore or maintain optimal crop yield for long term soil productivity is recommended.

Keywords: plant parasitic nematodes, maize yield, long-term, continuous cropping, organic amendments, urea fertilizer.

INTRODUCTION

The intensification of maize production, a major staple in Nigeria, has adversely affected the soil quality particularly in the various managed ecosystems of the northern Guinea savanna. Attempts have been made to improve the soil and crop productivity through sole or combined application of organic and inorganic fertilizers (Buresh *et al*., 1997; Vanlauwe *et al*., 2001). Long-term continuous cropping depending on crop species is known to increase plant parasitic nematode population. Continuous monocropping of maize have been reported to influence the build-up of plant parasitic nematode population which may remain stable for many years (Weber *et al*., 1995), thereby threatening sustainability of intensified maize-based systems. This is because conditions favorable for rapid increase in nematode population will cause severe crop damage resulting in yield losses. With continuous cropping and the use of fertilizer, yield of maize have been observed to be on average 1.36 tons ha^{-1} in Nigeria and this is about 20% of the average yield obtained in North America and other intensive maize producing regions in the world (Afolami and Fawole, 1991).

Some studies examined the effects of organic and inorganic soil amendments on plant parasitic nematode and maize yield under continuous cropping in different parts of the world (Weber *et al*., 1995; Neher, 1999).

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Few of these studies were conducted in this agro ecological zone.

This study therefore aimed to evaluate the interaction of soil fertility amendments (organic versus inorganic fertilizers) on the population of plant parasitic nematodes and the yield of maize.

MATERIALS AND METHODS

The field trial is a long- term experiment established in 1997 at the Institute for Agricultural Research (IAR) experimental site in Samaru, Zaria, Nigeria. The field is located at longitude 11.1591°N and latitude 7.6349°E at 683 m above sea level in the Northern Guinea savanna zone of Nigeria. The soil is sandy loam in texture and formed from aeolian deposits underlain by Basement Complex parent material (Moberg and Esu, 1991). It is a leached tropical ferruginous soil classified as Chromi-Epiferric Luvisol (FAO, 1998); or a Typic Haplustalf (USDA, 1998). Mean annual rainfall during the trial period was 1084.65mm and fall within the months of May- October while the average annual temperature was 26.36°C (IAR Meterological station, 2007). The treatments consisted of urea fertilizer, animal manure, *Centrosema pascuorum* and cowpea- *Vigna unguiculata* (legumes) applied at the rate of 90 kg N ha^{-1}. The legumes were intercropped with maize but after harvest the residues were incorporated into the soil as green manure. The treatments were applied using a randomized complete block design with three replications. Plot size was 6 m by 6 m with a total of 63 plots in the experiment. The animal manure was incorporated into the furrows about 10cm deep below the original soil surface, a week before planting. Each experimental plot consisted of 8 ridges with the four inner ridges used as net plots while the two outer ridges on both sides of the net plot as sampling plots. The maize seeds variety Oba Super II, which is a long duration (110-120 days), drought tolerant, and N efficient hybrid was sown (Heuberger, 1998). At 2 weeks after planting (2 WAP), urea was split–applied (⅓) for plots requiring urea fertilizer treatment. The remaining two third (⅔) of the urea fertilizer was applied at 5 WAP. The method of application was the same as in the first application.

Six soil cores (20 cm deep) were collected for nematode assays from the base of each maize plant at taselling stage from each of the four sampling plots of eight-row plots. The 24 soil cores were collected on a diagonal transects of each plot and bulked. The soils were thoroughly mixed to give a composite sample for each plot, sub samples were placed in nylon bags and stored at 10°C on the same day and kept for analysis. A 100g portion of soil was weighed out and placed on two sheets of kim wiper inside the extraction plates (Hooper, 1990). The soil samples were then spread evenly on top of the kim wiper. Twenty five ml of distilled water was poured inside the extraction plates and left for 2 days to allow the nematodes to migrate out of the soil samples into the water in the plates. The sieves (4 sets of 45 micrometer) were then removed gently and the extract collected in a 250ml beaker and left overnight to allow the nematodes to settle. The volume of extract was then concentrated to 10ml and poured into a 25ml measuring cylinder. The extract was thoroughly mixed and 1ml aliquot was taken and put into a Dohncaster counting dish for nematode counting under a dissecting microscope and differenciated (Hooper, 1970; 1990). Total numbers of nematodes/250cm^3 of soil were determined (but not corrected for extraction efficiency) from each treatment-replicate combination and nematodes were identified, into genera level and differenciated into plant parasitic and non-plant parasitic nematodes according to Bongers (1990).

Statistical Analyses: All data were statistical analysed using the General Linear Model Procedure of SAS (SAS Inst., 1999). Variance in nematode count was normalized by logarithmic transformation (Gomez and Gomez, 1984) and variance in proportion community composition was normalized with the arcsine transformation. Standard error of difference (SED) was derived from confidence limits from the least squares means procedure. Orthogonal contrasts were used to compare variability within and between soil amendments over the course of the experiment. Principal component analysis (PCA) was carried out on the plant parasitic nematodes for the treatments to identify the plant parasitic nematodes that most importantly explained variability in maize grain yield (Wander and Bollero, 1999; Kaiser, 1960).

RESULTS AND DISCUSSION

Grain yield: Animal manure + urea and sole urea applied at 90 kg N ha^{-1} had higher grain yield than the animal manure only (Table 1). However, the combination of organic and urea fertilizer was effective for animal manure as organic amendment but not effective for the use of legumes. Comparing the two sole urea only treatments (45 and 90 kg N ha^{-1}), there was no significant difference between the two treatments, although the yield was lower at 45 kg N ha^{-1} compared to 90 kg N ha^{-1} (Table 1). At the 90 kg N ha^{-1} level, yields from sole urea and animal manure+ urea were not significantly different. However, higher mean grain yield was obtained from the animal manure + urea treatment compared to the yield from sole animal manure treatment. Significant differences ($p<0.05$) were observed only between urea fertilizer (90 kg N ha^{-1}) and three other treatments -- *C. pascuorum* (45 kg N ha^{-1}), cowpea (45 kg N ha^{-1}), and cowpea + urea (90 kg N ha^{-1}) (Table 1). The magnitudes of yield changes required for significant differences were therefore increased because of the high variance in yield observed for sole application of urea yield data.

Table 1: Plant parasitic nematode genera and maize grain yield (kg ha^{-1}) at tasselling stage comparing S (sole organic or sole urea) and M (mixed organic and urea) at 90 and 45 kg N ha^{-1}.

Treatment	Plant parasitic nematode genera (250 ml^{-1} soil extract)					Grain yield (kg ha^{-1})
	HEL	PRA	SCU	HOP	APH	
Sole 45kgNha^{-1}						
Urea 1	296.67^{ab}	162.33^{ab}	106.67^{a}	263.00^{a}	32.00^{a}	504.80^{ab}
CP (only)	304.33^{ab}	142.00^{ab}	72.33^{b}	182.00^{bcd}	22.67^{b}	104.90^{b}
Pas (only)	376.67^{a}	169.00^{a}	117.00^{a}	268.67^{a}	37.00^{a}	468.60^{b}
Sole 90kgNha^{-1}						
Urea 2	191.00^{c}	110.33^{cd}	48.33^{c}	157.00^{cd}	0.00^{c}	1063^{a}
AM only	227.67^{bc}	97.67^{d}	49.33^{c}	131.67^{d}	7.67^{c}	579.30^{ab}
Mixed 90kgNha^{-1}						
AM + urea	249.67^{bc}	106.00^{cd}	51.67^{c}	151.67^{cd}	5.00^{c}	1055.60^{a}
Pas + urea	303.33^{ab}	134.33^{bc}	82.00^{b}	216.33^{abc}	20.33^{b}	544.80^{b}
CP + urea	345.67^{a}	155.67^{ab}	107.67^{a}	249.00^{ab}	30.33^{a}	450.50^{b}
SED/Significance	29.76 *	9.83 *	16.87 *	21.60 *	2.44 *	172.65 *
Contrast						
S45 vs M90	**	***	***	**	***	*
S90 vs M90	NS	*	NS	NS	*	NS
S45 vs S90	**	**	**	*	***	*

Means with the same letter in the same column are not significantly different, SED: standard error difference; NS: Not significant; urea 1 & 2: 45 and 90 kg N ha^{-1} respectively; AM: animal manure; Pas: C. pascuorum; CP: cowpea; M: mixed; S: sole; *,**,***: significant at 0.05,0.01&0.001 level of probability; HEL – Helicotylenchus; PRA – Pratylenchus; Scu-scutellonema; HOP – Hoplolaimus; APH – Aphelenchoides.

Results showed that the maize variety used in this study supported large numbers of PPN. This agrees with the findings of Norton (1983) who observed that any plant such as maize that supports large numbers of plant parasitic nematode increases the chances that the crop will be damaged resulting in low yield. This could be partly the reason for the low yields observed in this study. Secondly, wet, cool seasons were observed to be the most favorable period for the survival of *Pratylenchus* spp. both within and outside maize roots in this study. Egunjobi, (1974) reported that soil populations of *Pratylenchus* spp. reached a peak in June-July while root populations peaked at the tasselling stage growth. In the present study, this peak period of root populations coincided with the month of August which is the maize high vegetative growth stage (tasselling or silking stage). The high nematode population would have affected the critical growth and ear-filling stage of the maize crop resulting in low grain yield. The presence of *Pratylenchus* spp. in both the roots and soil suggested that this nematode species could be the major PPN parasitizing the maize plant. This species has been reported to cause major damage or loss in maize (Egunjobi, 1974; Norton, 1983; Alvey *et al*., 2003; Bulluck III *et al*., 2002).

Plant parasitic nematodes (PPN): No significant differences ($p>0.05$) were observed for PPN genera between the sole urea, sole animal manure, and animal manure + urea treatments at the 90 kg N ha^{-1} level (Table 1), although they had the lowest numbers of PPN (Table 1). The reduction in PPN populations observed with these treatments (90 kg N ha^{-1} sole or mixed with animal manure) could be due to the release of ammonium-N (NH^{+}_{4}-N) into the soil. This could be the reason for the higher maize grain yield obtained with these treatments though the recommended rates required to obtain significant suppression of nematode population and increased plant growth is generally in excess of 100 kg N ha^{-1} (Akhtar, 2000). Akhtar, (2000) observed lower PPN numbers with increased plant growth following additions of urea fertilizer applied between 110-220 kg N ha^{-1}. Also, the benefits of "balanced" organic and inorganic amendments for the Samaru site (Vanlauwe *et al*., 2002; Kolawole *et al*., 2007) may have contributed to improving the fertility status of the soil and reduced the incidences of PPN infection significantly between 3.4-80% compared to sole urea fertilizer application. Soils amended with organic materials were also reported to record lower numbers of PPN (Muller and Gooch, 1982; Chindo and Khan, 1990; Abawi and Widner, 2000). The significant difference between animal manure and legume mixed-fertility treatments observed with PPN genera was consistent with differences in grain yield data (though not statistically different) (Table 1). Numbers of *Aphelenchoides* sp. (APH) were higher in legume-amended than in animal-manure amended soils (Tables 1). This finding is not surprising as *Aphelenchoides* is a legume plant parasitic nematode (Bulluck III *et al*., 2002).

The increase in *Aphelenchoides* sp. in legume-amended treatments could be due to the presence of specific organic substrates in these amendments that favour the growth and development of this nematode species. Plant parasitic nematodes would therefore affect both the legume and *Rhizobium* in the nodules, and play an essential role in legume-*Rhizobium* symbiosis by causing a direct decrease in the primary production of the legumes. The overall effect of PPN on symbiotic N_2 fixation in legumes therefore depends both on the legume species and on the specific nematode present. *Aphelenchoides spp*., therefore, contributed to further yield decline in these legume treated plots.

No significant contrast was observed in PPN genera between sole and mixed - fertility treatments at the 90 kg N ha^{-1} except for *Pratylenchus* and *Aphelenchoides* sp (Table 1). From the result, *Pratylenchus* and *Aphelenchoides* parasitic nematodes were significantly contributing to grain yield decline, and this was indicated in the principal component analysis (Table 2). *Aphelenchoides* nematodes were significantly higher in *C. pascuorum*-only and cowpea + urea, compared to *C. pascuorum* + urea and cowpea-only. Higher numbers of *Aphelenchoides* in legume-amended treatments reflects the fact that *Aphelenchoides* is a legume-parasitic nematode.

Principal Component Analysis (PCA): Principal component analysis was carried out to identify the PPN population that most importantly explained variability in maize grain yield. From the results obtained, principal components with high eigen values were selected to best represent the variations in the soil fertility management practices (Wander and Bollero, 1999).Two principal components were greater than one (>1) and; cumulatively explained 91.65% of the variation within the soil fertility treatments (Table 2).

Table 2: Principal component analysis for plant parasitic nematode populations.

Measurements	Principal component	
	PC 1	PC2
	Biological parameters	
Eigen values	10.53	1.39
% Contribution	80.99	10.66
Cumulative percent	80.99	91.65
	Rotated score of two retained Eigen vectors	
HEL	-0.855	0.449
PRA	-0.961	0.230
SCU	-0.891	0.393
HOP	-0.897	0.346
APH	-0.954	0.149
TNem	-0.928	0.363

Only principal components with eigen values >1 and that explain >5% of the total variance were retained; HEL – helicotylenchus; PRA – pratylenchus; Scu-scutellonema; HOP – hoplolaimus; APH – aphelenchoides;, TNem – total nematode.

All six PPN retained were clustered together and there was a sharp drop in eigen values from PC1 to PC2. Only PC1 explained 81.0% of the total variance. All variables had negative loading. The PC2 explained an additional 10.66% of the total variance and was partially dominated by *Helicotylenchus.* The factor loadings showed the following ordination: PRA>APH>TNem >HOP>SCU>HEL. The peak period of root populations coincided with the high vegetative growth stage of maize in the month of August, thereby affecting growth and ear-filling stages due to competition for nutrients and water, resulting in low maize grain yield. Higher numbers of *Aphelenchoides* spp. in the legume treated plots as already mentioned would be due to the presence of specific organic substrates in these amendments that favour the growth and development of this nematode species. This could be partly the reason for the low yield of maize grain obtained in these plots.

CONCLUSION

The study showed that *Pratylenchus* and *Aphelenchoides* parasitic nematodes were significantly contributing to grain yield decline, and this was indicated in the principal component analysis. Higher numbers of *Aphelenchoides* in legume-amended treatments reflects the fact that *Aphelenchoides* is a legume-parasitic nematode. The incidences of plant parasitic nematode infection were significantly reduced between 3.4- 80% in soil by the mixed application of urea fertilizer and animal manure compared to sole urea application at 90 kg N ha^{-1}. However, the high consistent increase in PPN population showed that crop species had more influence than soil amendments. Continuous intensive cropping of maize favoured the build-up of PPN and would threaten sustainability of intensified maize-based systems in the NGS of Nigeria.

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